MORPHOLOGY AND PATHOMORPHOLOGY

FUNCTIONAL MORPHOLOGICAL CHARACTERISTICS OF THE STRUCTURE OF THE INTESTINAL MUCOSA OF RATS

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Physiological evidence of the periodicity of secretion of intestinal juice, first obtained by V. N. Boldyrev [1] in I. N. Pavlov's laboratory, has now been confirmed by the results of morphological studies.

M. I. Razumov [4] has shown that intestinal secretion is based on periodic accumulation of epithelial cells, in the form of elongated epithelial tubular processes at the tips of the villi, followed by shedding of these formations into the lumen of the intestine. The epithelium of the lateral walls of the villi is shed at the same time. As a result of these processes, the reticular stroma of the villi is divested of its epithelial covering for a certain time. The shed elements constitute the solid part of intestinal secretion, in which, according to G. K. Shlygin [8], S. Ya. Mikhlin [3], and L. S. Fomina [7], is contained up to 70-80% of the enzymes of intestinal juice. According to the observations of M. I. Razumov [4] the restoration of the epithelium of the villi proceeds through the stage of a symplast in dog's intestine; this was first described in the intestine of a growing carp (W. M. Smallwood and M. L. Smallwood [10]).

The object of our present research was to ascertain whether shedding of epithelial cells into the lumen of the intestine takes place in rats, and to find out whether the process has any distinguishing characteristics in this animal.

EXPERIMENTAL METHODS

Our experiments were performed on 40 rats, divided into several groups. The animals were killed at various times after feeding: 1) immediately after feeding (rats Nos. 33-35); 2) 2 hours after feeding (rats Nos. 30-32); 3) 7 hours after feeding (rats Nos. 27-29); 4) 24 hours after feeding (rats Nos. 1-23 inclusive); 5) 48 hours after feeding (rats Nos. 24-26); 6) under ordinary laboratory feeding conditions (rats Nos. 36-40) – excess food was given overnight, and the rats were killed at 9 a.m. the next day.

The animals were killed by decapitation, and were immediately opened up for sampling. Samples of duodenum, jejunum, ileum, appendix, and colon were taken, as well as of other viscera, for the purpose of assessing the general state of health of the animal. The material was fixed in Zenker's solution, ethanol, 10% formalin, embedded in paraffin and celloidin, and sections up to 6 μ thick were prepared. The sections were stained with hematoxylin-eosin, thionine, picrofuchsin, and tested for the Feulgen and Brachet reactions. Frozen sections were treated according to Foot for the staining of argyrophilic fibers.

EXPERIMENTAL RESULTS

Our studies showed that the structure of the intestinal mucosa of rats is distinguished by certain characteristic features. In contrast to the intestine of humans (N. Gundobin [2]), dogs (M. I. Razumov [4]), hedgehogs (J. Grimm [9]), and other animals, the duodenal mucosa of rats never forms circular folds. Circular folds are to be seen in the appendix of rats. The folds of the colonic mucosa cannot be considered to be Kerckring's folds,

as they are smoothed out when the colon is filled with fecal material.

Villi are to be found over the entire length of the duodenum and small intestine of rats. The villi are longest in the duodenum and the upper part of the small intestine. Within the ileum they are low, and have a cylindrical shape, or occasionally they appear as broad plates (in transverse sections). Villi are absent from the appendix and the colon.

The intestinal mucous membrane rests on areolar tissue, containing large numbers of argyrophilic fibers. These fibers are more densely distributed at the surface of the areolar tissue, immediately below the mucous membrane of both the glands and the villi. Side by side with the argyrophilic fibers in the central parts of the villi thin bundles of muscle fibers can be seen, constituting, together with the argyrophilic fibers, the basis of the stroma of the villi. Slender collagen fibers may be distinguished in small numbers in the areolar tissue of the glands, and along the course of the blood vessels of the villi, where they belong to the adventitial elements of the vessel walls. Argyrophilic fibers may also be found in the areolar stroma of the mucous membrane of the appendix and the large intestine, where they are thicker than in the small intestine. Apart from this, slender collagen fibers appear in the mucous membrane of the appendix and large intestine, in small numbers.

Wandering cells, consisting in rats of lymphoid elements, mast cells, and eosinophils with round, annular nuclei, are to be found within the meshes of the reticular syncytium of the stroma of the villi and glands of all sections of the intestine. It is known that in some animals, such as the dog (M. I. Razumov [4]), the lymphatic system of the stroma of the villi consists of a central lacteal, the walls of which are lined with reticular cells, and in other animals by a formed lymphatic duct lined with endothelium, as we have observed in rabbits. The lymphatic system of the villi of rats consists of a system of channels in the reticulum of the stromal tissue. These channels become regular, endothelium-lined lymph ducts in the vicinity of the intestinal glands.

The surface of the areolar stroma of the intestinal mucous membrane is covered with a layer of secretory epithelium, which in the rat includes goblet cells. The intercellular spaces of this epithelial layer may, as in other species, contain wandering cells, such as lymphoid elements and eosinophils. The number of such cells is, however, considerably smaller in rats than in rabbits. Not more than 50 cells can be found per histological section of the epithelium of a whole villus of a rat. In rabbits, 300 cells or more can be seen in one field of vision of a section of the epithelium of the small intestine, at a magnification of 10 × 40. The wandering cells infiltrate from the areolar stroma of the mucous membrane, and are mostly to be found in the basal parts of the epithelial layer.

Fig. 1. Epithelial tubes forming at the tips of villi in the ileum of Rat No. 14.
Stained hematoxylin-eosin, magnification 12x10.

Our observations showed that functional changes in the mucous membrane, associated with digestive processes taking place in the intestine, have the most pronounced effects on the structure of the epithelial layer. It was also found that the structure of the epithelial layer varies for rats or different groups, killed at different times after feeding. As in dogs, various stages, connected with the process of accumulation and shedding of cells, can be distinguished in the state of the epithelium of rats. In the early stages of accumulation of cells the superficial layer of epithelium at the surface of the mucous membrane of the villi forms a continuous sheet, closely approximated to the reticular stroma. As cells continue to accumulate at the lateral surfaces of the upper parts of the villi, the epithelial layer sometimes becomes thrown into shallow folds. More frequently, however, detachment of epithelial cells from the lamina propria of the mucous membrane takes place without prior formation of folds. This process first affects only the tips of the villi, and then spreads to their lateral surfaces.

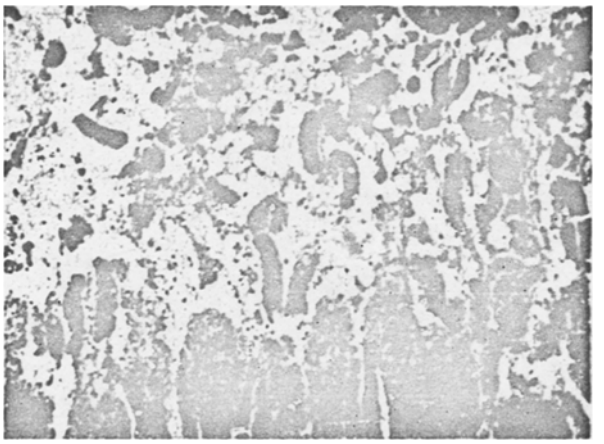

Fig. 2. Continuity of the epithelial layer interrupted, the upper parts of the villi denuded of epithelium; the lumen of the intestine contains shed tubules, fragments of tubules, and separate epithelial cells.
Stained hematoxylin-eosin, magnification 10 x 10. Rat No.34.

After the epithelial cells have been shed, protoplasmic strands emerging from the basal ends of the cells can be clearly seen in the gaps formed between the epithelium and the stroma when the cells were detached. Apparently these strands served for the attachment of the epithelial cells to the reticular stroma of the villi. With increase in the number of cells in the epithelium, and with its detachment at the tips of the villi, formation of epithelial tubules takes place (Fig. 1). These tubules are much smaller in rats than in dogs, as described by M. I. Razumov [4]. In both rats and dogs, the lumina of the tubules, and the gap remaining after their detachment, contain aggregations of granular protein, giving a positive reaction for ribonucleic acid. This granular formation was described by M. I. Razumov as being the fluid part of the intestinal juice. Isolated wandering cells, which had migrated from the reticular stroma of the mucous membrane were seen in the subepithelial granular substance of rats.

Shedding of epithelial tubules, their fragments, and of isolated cells into the lumen of the intestine supervenes at a certain stage of accumulation of cells in the epithelial layer (Fig. 2). As in dogs, the process spreads to the epithelium of the lateral surfaces of the villi. In such cases, the reticular stroma of the villi of rats, right down to the openings of the crypts, is denuded of epithelium, and is bathed in the contents of the intestine (Fig. 3).

Our studies showed that the nuclei of cells shed into the intestinal lumen of rats do not differ in their appearance and in their staining capacity, as well as in the distribution of chromatin within them, from those of the corresponding cells of the mucous membrane. The Feulgen reaction for deoxyribonucleic acid given by the nuclei of shed cells gives the same picture as is commonly seen in the cells of the mucous membrane of the intestine. We found that the shed cells are rich in alkaline and acid phosphatase, the distribution of which in the intestine of rats has been studied in detail by B. K. Skirko [5, 6].

Breakdown of the shed cells then takes place in the intestine, evidently as a result of the action of proteolytic enzymes of pancreatic juice, and structural changes are to be seen in the nuclei, which finally disappear. Aggregates of granular masses, staining intensively with eosin, are visible in the lumen of the intestine.

We found that shedding of cells into the intestinal lumen does not proceed simultaneously at all levels of the intestine, but takes place in a wave-like manner. Our observations showed that the structure of the epithelial layer of the intestine differs at different levels, for one and the same animal.

Our morphological observations show that the epithelial cells shed into the lumen of the intestine constitute the solid fraction of intestinal juice. In rats, the solid fraction consists of epithelial plasts, tubules, their

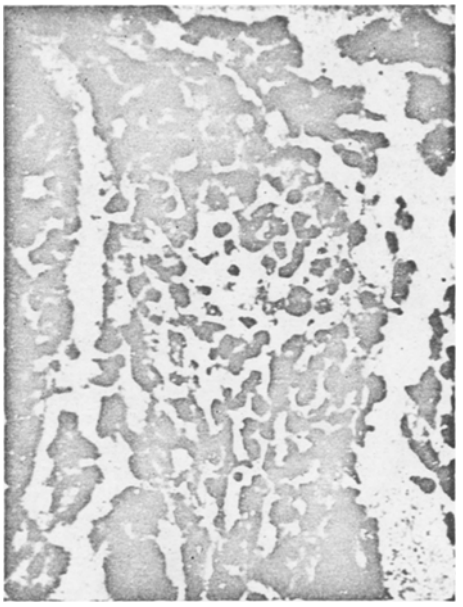

Fig. 3. Reticular stroma of the whole villus denuded of epithelium, and bathed in intestinal fluid, in which shed cells are visible. Stained hematoxylin-eosin, magnification 12 x 40. Rat No. 12.

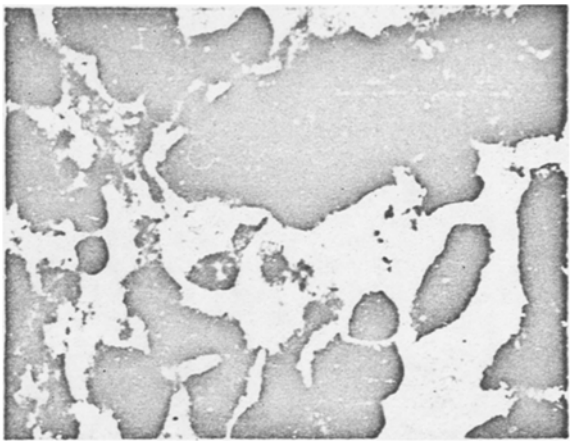

Fig. 4. Cells shed into the lumen of the intestine: epithelial and lymphoid cells, eosinophils. Stained hematoxylin-eosin, magnification 15 x 90. Rat No. 3.

fragments, and individual epithelial cells. Sporadic goblet and lymphoid cells may also be seen in the solid fraction. In contrast to dogs, the cells shed into the intestine of rats include individual eosinophils with round nuclei (Fig. 4).

We were unable to observe shedding of epithelial cells into the lumen of the appendix or large intestine, although in a few of the rats the intestine contained strands of cells with pyknotic nuclei and intensively staining cytoplasm. Such cells were in some cases present in a mass of foamy, apparently mucoid, intestinal content.

Our object in killing the animals at different times after feeding was to ascertain how the passage of food down the intestine affected the shedding process. Our morphological data, however, showed that the state of the epithelial lining varied in different rats killed at the same time after feeding.

SUMMARY

Intestinal mucous membrane was examined in rats, killed at various periods after feeding. It was established that there exists a regular disturbance in the continuity of the epithelial surface in the duodenum and small intestines of rats, i. e. there is an accumulation of epithelial cells on the villi in the form of epithelial tubes. Later these tubes and cells from the peaks and the sides of the villi are separated from the epithelial surface. According to the morphological data these separated cells form the solid fraction of the intestinal juice in the intestinal lumen.

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